Spatial and temporal simulation of groundwater age distributions of a small mountainous catchment

Anita Gundel [1], Markus Weiler [1], Mario Schirmer [2]

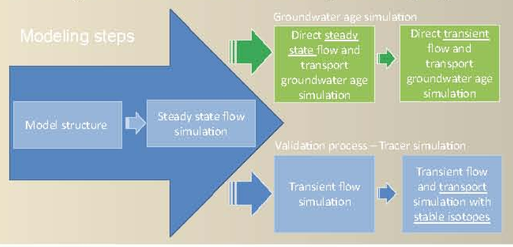
Introduction and Objectives

The spatial and temporal storage characteristics of catchments are relevant to identify their vulnerability to climate change. Areas with high mean groundwater ages imply long residence times of water particles in the aquifer. Therefore groundwater age is a good indicator for high storage capacity of a catchment. The great challenge for mountainous catchments is the steep topography and the complex geology which has the greatest impact on the groundwater age distribution. This study focuses on:

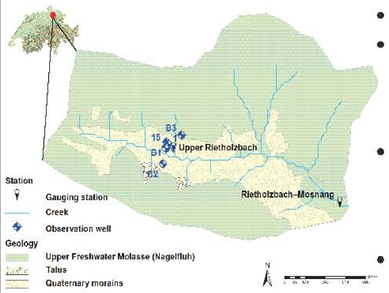
- Development of an explicit 3D numerical groundwater flow and transport model for direct groundwater age simulation
- Qualitative assessment of the spatial storage charateristics of an aquifer in Switzerland
- Utilization of stable isotopes for the validation of the numerical ground water model

Groundwater model

3D-finite-element groundwater flow and tranport model FEFLOW with transient direct mean age simulation based on a mass-weighted average age.



Study Site in Switzerland - Rietholzbach

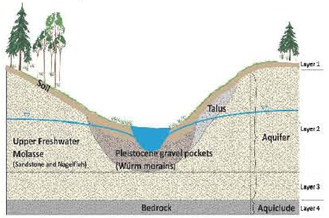


Geological map of the Rietholzbach catchment with the location of groundwater and discharge stations.

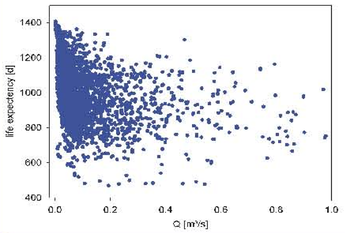
- **Area:** 3.18 km²
- **Altitude:** 682 m - 950 m
- **Land cover:**
  71.9 % pasture,
  25.6 % forest,
  2.5 % urban areas/ orchards
- **Geology:**
  Upper Fresh Water Molasse,
  Quaternary sediments,
  Talus
- **Data:**
  3 observation wells (bi-weekly),
  3 observation wells (h),
  2 discharge stations (d),
  1 metrological station (d),
  Irregularly water isotopes of discharge, groundwater, precipitation

Direct Groundwater Age Simulation

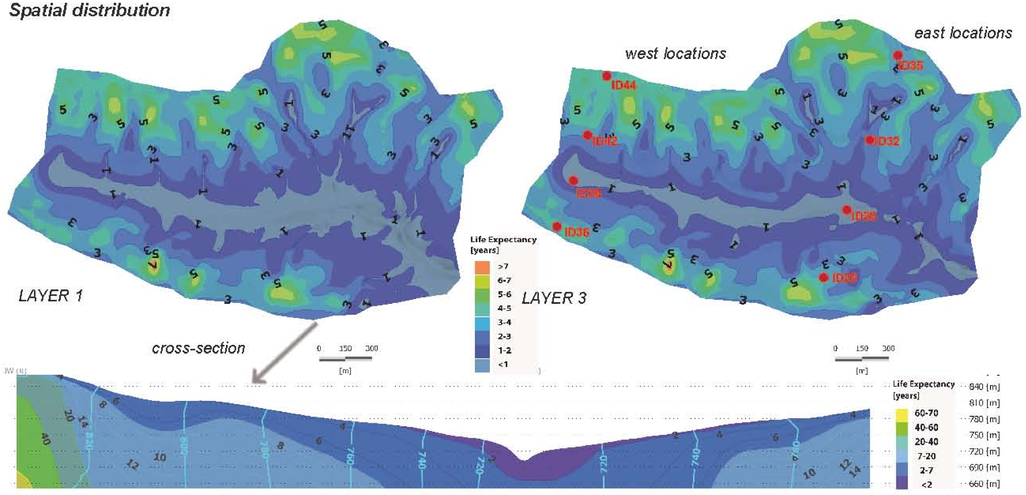
Cross-section of the Rietholzbach catchment based on geological map and borehole profiles.



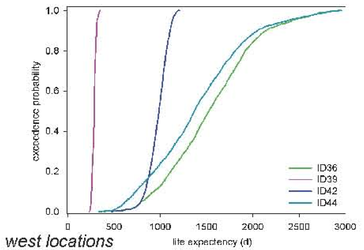
Good mixture of young and old water during low flow conditions and high proportion of young groundwater during high discharge conditions.



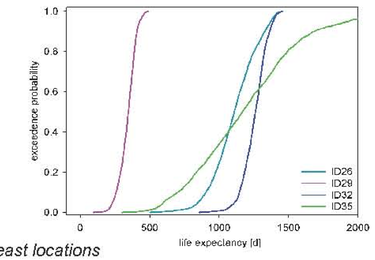
Spatial distribution



Temporal distribution of the several locations in the catchment



west locations



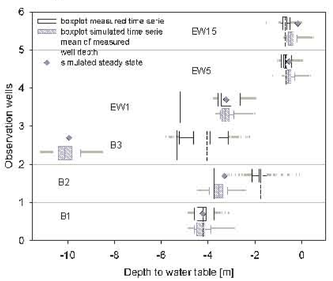
east locations

Age is defined as the time elapsed since the water particles entered the aquifer whereas life expectancy is the time remaining before leaving the aquifer. The graphs show the distribution of mean life expectancy.

Rietholzbach is a catchment with heterogeneous storage characteristics and long liefe expectancies, strongly influenced by topography. Under reverse flow conditions the travel time to the stream increases with distance and depth.

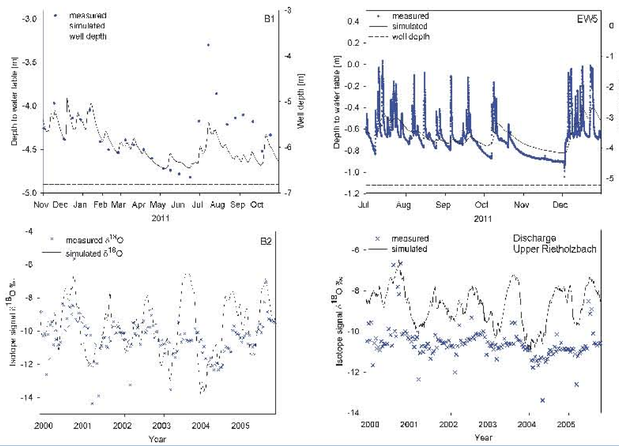
Validation Process

Steady state simulation

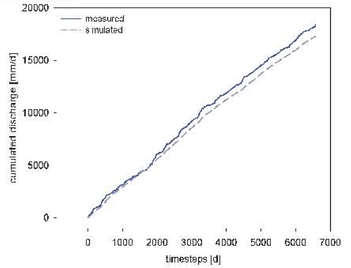


Compared to the observations the model adequately simulates the seasonal variation of the stable isotope signal. But it shows some bias for groundwater flow B2 and discharge Upper Rietholzbach.

Transient simulation



The model simulates adequately the groundwater flow dynamics. Differences between simulated and observed depth to the groundwater level mainly result from the initial conditions obtainted by the steady state simulation.



Simulated discharge compared with measured discharge at the outlet (Rietholzbach-Mosnang).

Conclusions

- The model is able to simulate the seasonal variations of the stable isotopes and their transport processes. Therefore they can be used as an additional and independent approach to validate 3D numerical groundwater models.
- The obtained long travel times indicate that it will be enough water during dry periods and implies that this catchment is less vunerable to climate change.
- 3D direct simulation of the mean groundwater age is a useful tool to increase the understanding of hydrological processes in space and time.

(1) Chair of Hydrology, University of Freiburg
anita.gundel@hydrology.uni-freiburg.de www.hydro.uni-freiburg.de

(2) Eawag: Swiss Federal Institute of Aquatic Science and Technology
www.eawag.ch

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